IMPROVED STRUCTURAL SANDWICH PLATE MEMBERS

The present invention relates to structural sandwich plate members which comprise two outer plates and a core of plastics or polymer material bonded to the outer plates with sufficient strength to substantially contribute to the structural strength of the member.

Structural sandwich plate members are described in US 5,778,813 and US 6,050,208, which documents are hereby incorporated by reference, and comprise outer metal, e.g. steel, plates bonded together with an intermediate elastomer core, e.g. of unfoamed polyurethane. These sandwich plate systems may be used in many forms of construction to replace stiffened steel plates and greatly simplify the resultant structures, improving strength and structural performance (stiffness, damping characteristics) while saving weight. Further developments of these structural sandwich plate members are described in WO 01/32414, also incorporated hereby by reference. As described therein, foam forms may be incorporated in the core layer to reduce weight and transverse metal sheer plates may be added to improve stiffness.

According to the teachings of WO 01/32414 the foam forms can be either hollow or solid. Hollow forms generate a greater weight reduction and are therefore advantageous. The forms described in that document are not confined to being made of light weight foam material and can also be make of other materials such as wood or steel boxes.

International Patent Application WO 02/078948 is a further development of the concept of including hollow forms and describes forms that are easy to manufacture and assemble, in particular hollow elongate forms made from snap-together pieces are described.

The basic forms of structural sandwich plate members described in US 5,778,813 and US 6,050,208 have excellent fire resistance properties, such plate members of dimensions suitable for ship building purposes easily pass

International Maritime Organisation (IMO) Safety of Life at Sea (SOLAS) A-60 fire tests, even without additional insulation. However, plate members such as those described in WO 01/32414 and WO 02/078948 do not pass these tests without additional insulation on the side exposed to the fire. Without such insulation the temperature of the unexposed side rapidly rises.

It is an aim of the present invention to provide structural sandwich plate members including lightweight forms within the core that have improved fire resistance and preferably can meet prescribed fire resistance test.

According to the present invention, there is provided: a structural sandwich plate member comprising: first and second outer metal plates; a core of compact plastics or polymer material bonded to said outer plates with sufficient strength to transfer shear forces therebetween; and a plurality of relatively lightweight forms disposed within said core; wherein said lightweight forms are made of a fire-resistant insulating material.

The present inventors have determined that prior art structural sandwich plate members with lightweight forms made of foam fail fire tests because the foam melts quickly leaving relatively large voids extending between the faceplates of the panel. Where the lightweight form is hollow, the voids exist from the outset. The air and other gasses in those voids can then conduct heat to the panel on the side away from the fire. By making the lightweight forms out of a fire resistant material, such as mineral wool, this is avoided. The form does not melt and so there is no large open void across which heat can be conducted by convection.

Preferably the lightweight form should be made of a material having an ignition point and a melting point higher than 1000°C.

In a preferred embodiment of the invention, the lightweight foam comprises fire resistant material encased in a barrier impermeable to the liquid form of said plastics or polymer material.

With this arrangement, the plate member can be made by injection molding after placement of the lightweight forms in a cavity made by the two outer plates, as described in WO 01/32414 and WO 02/078948. The barrier

prevents the liquid plastics or polymer material soaking into the insulating material. For example, the lightweight forms may comprise a preformed type, made of solid plastic, foam, metal or other material, into which the insulated material is placed. In that case, the form may be constructed as in any of the embodiments described in WO 02/078948. Alternatively, the insulating material may be shaped to the required geometry and sprayed or dipped in a coating material which hardens to provide the outer layer. A further alternative is to wrap the insulating material in a thin outer layer such as metal foil, felt or mineral cloth.

The insulating material is preferably mineral wool and may have a density in the range of from 30 kg/m^3 to 200 kg/m^3.

It should be noted that the lightweight forms serve to reduce the mass of the structural sandwich plate member and need not contribute significantly to its structural strength. The principal requirements on the lightweight forms are that they are of lower density than the plastics or polymer material forming the core and have sufficient thermal and mechanical properties to maintain the desired shape during injection and curing of the plastics or polymer core. The layout of the forms within the core may be as described in WO 03/101728.

The materials, dimensions and general properties of the outer plates of the structural sandwich plate member of the invention may be chosen as desired for the particular use to which the structural sandwich plate member is to be put and in general may be as described in US-5,778,813 and US-6,050,208. Steel or stainless steel is commonly used in thicknesses of 0.5 to 20mm and aluminium may be used where light weight is desirable. Similarly, the plastics or polymer core may be any suitable material, for example an elastomer such as polyurethane, as described in US-5,778,813 and US-6,050,208.

Further, the invention provides a method of manufacturing a structural sandwich plate member comprising the steps of: providing first and second outer plates in a spaced-apart relationship with a plurality of lightweight forms located therebetween; injecting uncured plastics or polymer material to fill the space defined between said outer plates and said lightweight forms; and allowing said

plastics or polymer material to cure to bond said outer plates together with sufficient strength to transfer shear forces therebetween; wherein said lightweight forms are made of a fire resistant insulting material.

The present invention will be described below with reference to exemplary embodiments and the accompanying schematic drawings, in which:

Figure 1 is a plan cross-sectional view of a structural sandwich plate member according to a first embodiment of the present invention;

Figure 2 is a cross-sectional view of a structural sandwich plate member according to a second embodiment of the present invention; and

Figure 3 is a cross-sectional view of a structural sandwich plate member according to a third embodiment of the present invention.

In the various drawings, like parts are indicated by like reference numerals.

The structural sandwich plate member shown in Figure 1 comprises upper and lower outer plates (faceplates) 11, 12 which may be of steel and have a thickness of *e.g.* in the range of from 0.5 to 20mm. Edge plates are welded between the faceplates 11, 12 around their outer peripheries to form a closed cavity. In the cavity between the faceplates 11, 12 is a core 13 of plastics or polymer material, preferably a compact (i.e. unfoamed) polyurethane elastomer. This core may have a thickness in the range of from 15 to 200mm; in the present application 160mm is suitable. The core 13 is bonded to the faceplates 11, 12 with sufficient strength and has sufficient mechanical properties to transfer shear forces expected in use between the two faceplates. The bond strength between the core 13 and faceplates 11, 12 should be greater than 3MPa, preferably 6MPa, and the modulus of elasticity of the core material should be greater than 250MPa. For low load applications, such as floor panels, where the typical use and occupancy loads are of the order of 1.4kPa to 7.2kPa, the bond strength may be lower, *e.g.* approximately 1MPa. By virtue of the core layer, the structural sandwich plate member has a strength and load bearing capacity of a stiffened steel plate having a substantially greater plate thickness and significant additional stiffening.

To reduce the weight of the structural sandwich plate member 10, not all of the volume between the faceplates 11, 12 is occupied by core 13. Instead, an array of lightweight forms 14 is provided, occupying a substantial part of the internal volume of the plate member. The lightweight forms 14 do not need to significantly contribute to the structural strength of the plate and they require only to have thermal and mechanical properties sufficient to withstand the pressure of injection of the material to form core 13, the heat from the exothermic reaction of the core during curing and temperatures experienced during fires.

The forms 14 comprise a hollow pipe 15 filled with fire resistant insulting material 16. The pipe 15 serves to prevent the liquid core material during injection molding of the core from soaking into the insulating material which ensures that there is no large void extending through the core material even during fire conditions reducing heat conduction between the faceplates 11, 12. The pipe 15, although illustrated as circular in section, may take many other forms, including rectangular, hexagonal, or octagonal sections and may have ribs internally to provide additional strength or externally to space the form away from other forms, the edge plates, or the faceplates. In general, the pipe may take any of the forms described in International patent application WO 02/078148. The insulating material is preferably mineral wool, for example as supplied by Rockwool Limited of Pencoed, Bridgend CF35 6NY, UK. The insulating material may have a density in the range of from 30 kg/m^3 to 200 kg/m^3 and preferably has an ignition point and melting point higher than 1000°C, preferably.

To manufacture the structural sandwich plate member 10, the edge plates are welded around the periphery of lower faceplate 11 and then forms 14 and any spacers placed in the resulting open cavity. At this stage, any precast sections of the core may be put in place as well as any shear plates or other fittings that may be desired. Then, the upper faceplate 12 is welded to the edge plates to form a closed cavity and the plastics or polymer material injected to form core 13. The injected material is then allowed to cure and the injection ports used in the injection step ground off and sealed along with the vent holes. These steps may be

performed in situ, or off-site in factory conditions and the finished panel transported to the installation site.

A second embodiment of the present invention is shown in Figure 2. The structural sandwich plate member 20 according to the second embodiment of the invention is similar to the first embodiment but different in the construction of the lightweight forms, as described below.

In the second embodiment, the lightweight forms 24 comprise blocks 26 of insulating material which are formed in the desired shape. As illustrated, the blocks are square in section but may be rectangular, hexagonal, octagonal or other shapes in section and may have a uniform section or vary in cross-section along their lengths. To prevent the liquid core material soaking into the insulating material during injection, the blocks 26 of fire resistant insulating material are sprayed with or dipped in a coating material which hardens to provide an impervious outer layer.

Figure 3 illustrates a third embodiment of the present invention which differs from the second embodiment in the manner of formation of the barrier around the insulating materials. In the third embodiment, the blocks 36 of fire resistant insulating material are wrapped in a sheet material 35, rather than being coated. The sheet material 36 may, for example, comprise metal foil, felt, mineral cloth or suitable plastics or polymer sheet.

It will be appreciated that the above description is not intended to be limiting and that other modifications and variations fall within the scope of the present invention, which is defined by the appended claims. For example, if the core of the structural sandwich plate member is formed by precast elastomer blocks, the barrier enclosing the fire resistant insulating material may be omitted. Also, where the lightweight forms extend between the faceplates of the structural sandwich plate member it may suffice to provide a barrier only on the sides of the lightweight forms which will come into contact with the core material rather than

fully encasing the forms. A separate barrier may also be omitted if the insulating material, or at least a surface region of the form, is sufficiently dense that ingress of liquid core material during molding is limited.